LATIMER, (T.S.)

Report of the Section on Anatomy, Physiology, and Pathology.

Deep Reflexes in Health and in Disease.

By THOS. S. LATIMER, M. D.

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DEEP REFLEXES IN HEALTH AND IN DISEASE.

By Thos. S. Latimer, M. D.

The clinical significance of knee-jerk has been somewhat impaired by the different views as to its essential nature and the diverse statements as to its presence or absence under similar circumstances. I have thought, therefore, that a brief examination of recent studies, clinical and physiological, would be of practical importance and not without interest to the Faculty. It will be remembered that it is now about nine years since Westphal and Erb announced the absence of this phenomenon in tabes dorsalis. The observations of Bernhardt subsequently showed that in all but two of 46 cases it was wanting; and Berger found that in 1409 healthy individuals it was absent in only 1.56 per cent. A condition so uniformly present in health, so easily observed, and frequently absent or exaggerated in particular groups of diseases, has naturally been observed by many capable and careful persons, and as a result it may be said to have drifted into comparative clinical disfavor; and none of the explanations as yet offered as to the essential character of the relations normally existing between muscle and nerve fibres and nerve centres concerned in this manifestation can be considered entirely satisfactory. That the jerk following the tap on the patella ligament is not a purely reflex act, as at first thought, is now generally conceded, the principal objection to this view being that the time between the tap and the contraction is not sufficient for the shortest reflex known, and that the period is the same whatever the length of the nerve, and the same as when the muscle is directly stimulated. Lombard, however, justly remarks that we know too little of reflex times to warrant any positive conclusion on this score. The explanation perhaps most generally accepted at present, that the tonicity of the muscle is reflex,

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and the contraction the direct effect of the tap on tendon or muscle, for which a certain degree of tension is necessary, is also open to objections, since in the absence of one or more of the reflex factors, when extensile stimulus does not induce contraction, direct percussion of the muscle will, owing, according to Hughes Bennett, to irritability of the muscle fibre.

The experimental study of the knee-jerk phenomenon by Lombard, with exact measurement of force employed, amplitude of swing, and of the normal constantly varying conditions affecting it, is full of interest, and may be advantageously considered in advance of the clinical conditions causing variation. His experiments were made on himself (Amer. Jour. of Psychol., Nov. 1887), lasting through a period of six weeks, at 239 different times, in all 6639 observations. These experiments seem to demonstrate, as far as observations on a single person can, that in health many trivial circumstances produce important modifications in the jerk. He used a hammer, always the same, let fall from the same height on the same part of the patella tendon, the leg always in the same position. The amplitude of the resulting swing was measured in each case and found to vary with the time of day, the period that had elapsed since taking food, his mental state, his condition of weariness or activity, mental or muscular, the external temperature and barometric condition.

Anything occasioning exaltation of vital activity reinforced the jerk, and everything of an opposite character weakened it. The extent of the jerk varied with the force of the blow, and on different days, at different periods of the same day, and even in the same experiment. It would seem, he says, as if the nervous connections were so intimate that a change in the activity of any one of these centres (cord or brain) would make itself felt in all the rest, as if, to speak figuratively, there was a balancing of nervous tension throughout the nervous system, so that a change in one part must be felt in all parts. Any strong sensory irritation, voluntary muscular contraction, or even an emotion, influenced the extent of the jerk. Ernest Yendrassik, in 1883, had observed the reinforcement induced by clenching the hands, and Weir-Mitchell and Morris J. Lewis, in 1886, corroborated and extended his observations, but the experiments of Lombard are more exact and embrace a greater number and variety of conditions. He found that no two jerks, produced under exactly similar circumstances, so far as could be determined, were exactly alike. Simply clenching the teeth or hand occasioned such marked rein-

forcement as to lead to the conclusion that the unknown reinforcing conditions might in many cases be very slight. A regular diurnal decline, interrupted at meal-time, was observed, beginning after breakfast. The average with subject out of bed and not yet thoroughly aroused was low fifteen minutes after it was higher, after taking a bath it was still higher, after breakfast it was still higher, after which there was a regular decline, with slight interruptions at meal-times, and at bed-time it was lower than before the morning bath. The highest average was usually just after breakfast. To this there were exceptions, however, without appreciable reason. No wine or beer was used at meals, though coffee and tea were.

The extent of the jerk was generally greater after eating, but mental states were found to cause variation in this respect. Muscular exertion, "even a short stroll," lessened it, as did also mental fatigue, though slight mental exertion did not. Unusual mental activity, especially of an emotional character, reinforced the contraction. Itching, tingling of skin, a crease in clothing, or any uncomfortable sensation, caused increase, as did the slightest voluntary movement, especially when the blow was delivered at the right moment. Sounds which caught the attention augmented the jerk, when sensory auditory disturbances of a more decided character which did not rise into attention had no appreciable effect. Cerebral inactivity and sleep diminished the effect. Mental activity unattended with emotional excitement made no appreciable difference, but if attended with excitement, greatly increased the movement; for instance, simply multiplying occasioned no change, but endeavoring to do so hurriedly, with anxiety about the result, did. Having previously ascertained the amplitude of the swing to average 27 mm., it was found to reach 64 mm. whilst reciting "How they brought the good news from Ghent to Aix." It is probable in this case that the mental activity involved in the act of memory, the emotional excitement induced by the spirit of the poem, and the contraction of the laryngeal muscles, combined to produce this result. The average extent of jerk at 10.30 A. M., during quiet, was 30 mm., but when a skillful pianist played Beethoven's "Funeral March" the jerks were 82, 104, 96, 105, 104, 99, 108, 95, 106, 118, 117, 90, 113, 119, 97, 100, 124, 108, 112—average 105. After an interval of quiet the jerks fell off 83, 90, 90, 66, 82, 59, 75, 50—average 74. Then Chopin's "Raindrop Prelude" was played, and during the soft music, when the raindrops are supposed to be falling, the extent of the jerk was 52, 63, 47, 50, 55; as the music

changed and the deeper passages began to make themselves felt it was 66, 73, 58, 78, 70, 86, 77, 87; as the music subsided and became softer the measurements were 66, 43, 59, 62, 70, 68, 54; as the more thrilling passages succeeded, 79, 86, 86 was measured, and finally, as the varied but softer parts came again, the knee-jerk was 58, 57, 79, 67, 47. Dreams of an exciting character were also found to reinforce it. Increase of temperature lessened the extent of the jerk, especially when associated with a low barometer. Rise and fall of barometer was directly accompanied by rise and fall of the jerk. A change in the direction of the wind, a change in the electric potential of the atmosphere, and slight changes in relative humidity of the air, are without influence on the knee-jerk and presumably upon the central nervous system.

It also calls attention to the fact that the variations of the barometer and the thermometer, though of the greatest importance in determining the height of the daily average of the knee-jerk, are secondary to hunger and fatigue in their effects on its hourly variation. In a second series of experiments extending over two weeks and including 3156 experiments, all the observations and conclusions of the first series were corroborated.

It will be of interest, in connection with these experimental observations on the healthy subject, to consider the clinical aspects of the knee-jerk and the pathological lesions found associated with it. The whole matter was very forcibly discussed by the ablest men in Great Britain in the Neurological Society of London in July last, the discussion having been elicited by a most excellent paper on "Muscular Hypertonicity in Paralysis," read by Dr. Hughes Bennett (Brain, Jan. 1888). Dr. Bennett undertook to show the frequent connection of motor weakness with increased muscular tonicity as manifested in the knee-jerk, and then hazarded, as he expresses it, such explanations of its phenomena as seem warranted by the present state of scientific knowledge. A series of cases are reported, at first presenting no symptom of disease but slight motor weakness with exaggerated knee-jerk; this condition continues for months or even years with but little appreciable change. Gradually the weakness increases, though still associated with otherwise robust health. The most careful examination reveals nothing abnormal but this motor weakness and increased muscular contraction on percussion of its mass or tendon. All the ordinary movements are still executed, though somewhat feebly, and the person is quickly exhausted. There

are no peculiarities of gait except those indicative of muscular feebleness. In like manner the upper extremities are easily wearied in writing, sewing, or other accustomed exercises. No cramp, pain, or inco-ordination accompanies any movement. The knee-jerk is the same in kind as in health, but altered in degree within wide limits, from the slightest increase to the most extreme demonstrations of muscular irritability. In advanced cases trepidations and cloni may be induced in various situations; tapping the bone is sometimes sufficient to induce contractions in adjacent muscles. No spasm or rigidity of muscle, no loss of electrical reaction, no trophic changes beyond that physiological atrophy usually accompanying inaction, no sensory disorders of any kind whatever. The functions of the different organs are unimpaired, except that occasionally ability to retain urine is slightly lessened. Intelligence remains normal. The superficial reflexes are unimpaired. The trouble affects the lower extremities most frequently, usually beginning in one leg and gradually extending to the other, though occasionally remaining limited to one leg; not infrequently it extends to the arm of the same side, but usually both are affected, though to a different extent. Occasionally every muscle of the body shows signs of weakness and is hyper-sensitive to percussion. In one case related by Dr. Bennett, clonus could be produced by tapping the tendon of any muscle, "including those of the face, neck, and trunk." This case continued for two years and ultimately recovered. The duration of this trouble is very variable. One case related by Bennett lasted eight or ten years without perceptible change, whilst another, in which most all of the muscles were decidedly affected, recovered "in a few weeks with rest and large doses of chloral hydrate." No syphilitic connection nor difference as to sex has been noticed. No hereditary predisposition to this or other forms of nervous disease except that in one instance two brothers were affected. It occurred between the ages of twenty and forty in Bennett's (twenty) cases. It will be observed that it sometimes gets well, sometimes continues unchanged, and sometimes progresses from below upward.

Changes either in the direction of recovery or increase of the disease are usually slow. It is but little affected by treatment, and "the muscular irritability to percussion does not diminish in a corresponding ratio with the increase in muscular strength." Here certainly is a clinical picture of sufficient clearness—muscular weakness with increased irritability as manifested in the reaction to percussion.

What are the causes and the pathology of a disease strictly limited symptomatically to the muscles and motor elements of the nervous system, and in which there is no evidence of disease in the muscle fibre, and in no other tissue or organ any abnormality of function or structure?

Clearly the explanation must be sought in the nervous system, and we are brought at once to the inquiry, what are the nervous elements in exaggerated muscular contraction upon percussion of tendon or mass? Healthy muscle, we all know, contracts when suddenly stretched by a blow on its mass or tendon, or by other forms of sudden stretching. The mechanical condition precedent for the production of this phenomenon is "sufficient passive tension of the muscle fibre," the so-called "reflex tonicity," "state of slight constant tension which is the characteristic of healthy living muscle." Bennett maintains:

1st. That both are *abolished* when there is interruption at any portion of the reflex arc of which muscle is the terminus.

2d. Both are *increased* by causes which augment the excitability of the same reflex mechanism.

(*a*) Idiopathic excitability of reflex centres of cord.

1. Isolated, as in strichnine poisoning.
2. Associated, as in neurasthenia.

(*b*) Excitability of reflex centres, secondary to:

1. Direct influence from afferent and efferent elements.
   (*a*) Afferent (reflex), as from cutaneous or visceral irritation.
   (*b*) Efferent (exhaustion), as from fatigue or over-exhaustion.
2. Indirect influence, as result of severance from pyramidal tract. This is variously explained by:
   (*a*) Irritation of sclerosed lateral columns.
   (*b*) Removal of cerebral inhibition.
   (*c*) Unbalanced cerebellar action.
   (*d*) Nutritive changes in ganglia due to severance from trophic centres of cortex.

Dr. Bennett claims that the integrity of each portion of the reflex arc is necessary for the maintenance of muscular tonicity and the response of muscle to extensile stimulus on percussion; but he elsewhere admits, in responding to the criticism of Dr. Buzzard, that either factor of the reflex arc may be abolished and still leave the muscle responsive to percussion; as in tabes dorsalis, where the afferent factor is absent; in anterior polio-myelitis, where the motor cells

are stricken; or in injury, accidental or experimental, to the motor fibres if only the muscular irritability be exaggerated. If contraction of a muscle upon percussion of its mass, and to a greater extent of its tendon, is due to its tonicity, and that tonicity requires the integrity of all parts of the reflex arc, as Dr. Bennett maintains, then it seems quite clear that contraction should not result on percussion when one or other of the nerve factors is entirely withdrawn.

Dr. Bennett admits that even exaggerated contraction may occur in tabes on percussion of the muscle when percussion of its tendon gives no response, and says the difference is due to the absence of the afferent factor.

Dr. Buzzard also states that in many cases of muscular atrophy associated with bilateral sclerosis, whilst the tendon phenomenon is greatly exalted there may be scarcely any response to percussion of the muscle substance, and that exactly the reverse of this is the case in Thomson's disease, which is characterized by an exaggerated tendency to muscular contraction on the slightest stimulation.

He likewise states with great force, it seems to me, that in cases where all the phenomena usually relied on to indicate muscle-health, such as normal response to electric stimulation, voluntary control, state of nutrition, were present in equal degree on both sides, yet percussion of the tendon on one side gave no response whilst it was but little if at all changed on the other, yet direct percussion of the muscle caused, to the eye, an exactly similar contraction in each. These are difficulties that interfere with the "acceptance of the view that the so-called tendon-phenomenon is but the contraction of a muscle submitted to sudden stretching, its fibres being in the requisite state of tonicity."

Dr. Bennett, in closing the discussion, says in reference to this branch of his subject: "It may also be concluded that percussion of a muscle may cause contraction for more than one reason, namely, from extensile stimulus, from direct irritation of motor nerve, and from direct irritation of muscular fibre, therefore reaction following a blow does not negative the absence of tonicity."

It is to be regretted that the experiments of Lombard did not embrace any comparative observations as to the relations borne by direct muscle percussion to tendon-tap in health. That muscular hypertonicity and the response to percussion are increased by anything that augments the excitability of the reflex arc, and that the essential factor is exaggerated excitability of the ganglion cells of the

cord, is ably argued by Dr. Bennett, who says also that this excitability of the ganglion cells may be brought about in three different ways:

1st. Irritation arising primarily in the ganglion cells themselves.

2d. Their irritation due to changes in their afferent and efferent elements.

3d. Their irritation secondary to influences acting through the pyramidal tracts.

The spinal centres, he says, may be rendered hyper-excitable in many ways, as by strichnia, nervous exhaustion, anaemia in states of subnormal nutrition, etc., and it seems "a neurological law that nervous depression is associated with instability of function, excessive motor display, and an abnormal readiness to respond to stimulation." This is illustrated in children whose nervous system is imperfectly developed, where the prevailing types of nervous disease are motor disturbances as in convulsion, chorea, tetany.

In the adult also, after loss of blood, in phthisis and most exhausting diseases, and in convalescence, exaggerated knee-jerk is frequently found, and generally disappears with recovered strength, and in these conditions our author thinks the grey matter of the cord shares in the general debility and associated excitability. These observations are, I believe, in accord with general clinical experience, and yet it will be observed they are exactly the reverse of what the experimental observations on the healthy subject would lead us to expect, since even a short walk, general lassitude, or any mental or physical activity tending to exhaustion, lessened the extent of the knee-jerk in Lombard's experiments. That peripheral irritation augments the excitability of the ganglion cells, or at least augments the tendency to contraction on percussion, is in accord with both clinical and experimental observation. Wounds, visceral irritation, burns—in short, irritation of any sensory nerve, may induce hyper-excitability of the cord, and in such cases at least it may properly be called reflex excitability. Lombard found a crease in his clothing reinforced the knee-jerk, and Brown-Sequard demonstrated that injury to sensory nerves may induce "so-called spinal epilepsy—in other words, a chronic state of hyper-excitability of the grey matter of the cord."

The sensory irritation of the auditory nerve in Lombard's musical experiments, whether the effect was due to the mental state induced or not, seems to belong properly to this group of modifying influences, although notes of music which did not catch and fix the attention

produced less effect than those that did; it is not unlikely that the same would hold good of the cutaneous impression from the crease in the clothing. And the fact that sensory disturbance on one side of the body may occasion reflex excitability not only on the same side of the body and for the same segment of the cord, but on the other side and in various segments, indicates direct propagation of the impulse from cell to cell.

Drs. Weir-Mitchell and Donkin have recently shown that exhaustion is a fertile cause of spastic paralysis, which may be looked upon as a further stage of hypertonicity. There seems to be no very good reason for speaking of impressions reaching the cord through the pyramidal tracts, whether volitional or directly evoked through special sense channels, as different in essential character from peripheral irritations. The impulses traversing these tracts are afferent to the spinal ganglion cells, and bear the same relations to their state of reflex excitability that other afferent impulses do. Slight stimulation of the cortical motor centres directly or indirectly through the sense organs appears to augment their excitability, whilst greater or long continued excitation exhausts them. Thus stimulation of the cortical centres in the Rolandic region, or irritation by disease, will cause muscular contraction, passing into spasm or paralysis according to the degree or duration of the irritation; and Bennett says he has often satisfied himself "that in addition to the spasm, the tonicity of the muscle was augmented, as evinced by an increase of the knee-jerk." Irritation of any portion of pyramidal tract will be attended with similar results. That destruction of the cortical centres or complete severance of the cord is attended by slowly developing hypertonicity sequent upon hyper-excitability of the ganglion cells, is explained by Bennett and Ferrier as due to the descending degeneration giving rise to irritation of the ganglion cells through the extension of the morbid condition to them, which, however, stops short of appreciable structural lesion in them. This is substantially the view of the French school, except that this school holds that the contiguity of the lesed fibres finally occasions irritative changes in the ganglion cells.

The increased knee-jerk of hysterical states, or attending mental exhilaration, or voluntary muscular contraction, all indicate that this hyper-excitation of ganglion cells in the anterior cornua may be brought about by physiological stimuli, producing no structural change in fibre or cell beyond those molecular changes that accompany

all nutritive and functional activity in every tissue, passing into grosser appreciable change from increase in degree or duration of the exciting cause. Temporary hypertonicity is induced by transitory stimulation in a perfectly healthy subject. Permanent hypertonicity may be induced by more continuously acting causes.

We find, in advancing along the scale of animal evolution, an increasing solidarity of the nervous system, always accompanied by a closer association of the physiological activities peculiar to each part, until, in the highest vertebrates, the different parts are so closely united histologically and functionally that we may fairly assume—and the experiments of Lombard and others seem to place this assumption on basis of fact—that no normal activity under purely physiological conditions can occur in any part without calling forth echoes from every part. As a strain of music through the auditory nerve excites the activity of the associated cortical cells, which pass on the molecular action to underlying fibres and their associated centres, until the ganglion cells in the anterior cornua, their associated nerve and muscle fibres, are all brought into a state of erythism, evidenced by readiness to contract on the application of a stimulus at the muscle terminus, not of the reflex arc, but of the entire nerve-muscular mechanism. Dr. Bennett's summary of this complicated inquiry is so clear that I cannot do better than to quote his words: "It is suggested that increased muscular tonicity, from whatever cause arising, is essentially due to abnormal hyper-excitability of the motor ganglion cells of the anterior cornua of the cord. The hyper-excitability may, for various reasons, be due to idiopathic alteration of the cells themselves, or may be induced therein by influences emanating from the brain, the cord, or the peripheral nerves. These influences are probably of an irritative nature, and may therefore be considered as a new morbid process. This irritation, when it exists in the pyramidal tract, may be excited there either directly by organic disease or functional excitement, or indirectly by changes in its nutrition as a result of severance from its trophic centres. These changes in nutrition may be either gross or dynamic. The gross changes usually follow gross disease of the cortical centres, while the dynamic changes may either follow their structural alterations or their functional disorder. Finally, this functional disorder of the motor tract may have its origin of psychical as well as of motor centres."

The views of the French school, endorsed by Bennett and by Ferrier,

and modified by study of Lombard's experiments, seem to the writer to be open to fewer objections than the antagonist theories. They may be briefly stated thus: Hypertonicity of muscle is usually essentially dependent, in health or disease, on hyper-excitability of the ganglion cells, however induced, whether by mental activity, emotional excitement, direct stimulation of the grey cortex or any portion of the nervous mechanism intervening between the hemispheres and the particular segment of the cord so excited, or by stimuli of any kind, psychological or pathological, affecting cutaneous or visceral fibres belonging to our segment or to any other segment; or directly affecting the cells in posterior or anterior cornu of the same segment; or of any underlying posterior or over-lying anterior segment; but that contractions may be induced after severance of the cord from the muscle by accident or design, on stimulation of the motor nerve fibres or muscle fibres by a direct blow.

This view, however, that excitation of the cells in the anterior cornua is the prime factor, did not meet with general acceptance. Dr. Hughlings Jackson ably contended for the cerebral inhibitory and cerebellar direct hypotheses. In a case of hemiplegia attended with exaggerated knee-jerk, he considers that the anterior horns are in a state of exalted activity from the absence of inhibitory control, rather than from the irritation sequent on the degeneration of the fibres of the lateral column; and he argues that the fact that in some cases there is slight wasting of the muscles from the descending degeneration militates against the idea that this degeneration can produce the opposite effect, "exaltation of function." Increase of knee-jerk in hemiplegia is for him simply a hyper-physiological condition; although this of course involves, he says, increased nutritive changes. "Being 'cut off' from the higher (cerebral) centres, the anterior horns in question are 'let go'; they gain autonomy." He also suggests that the withdrawal of the inhibitory influence of the cerebrum strengthens the direct influence of the cerebellum. In support of these views Dr. Jackson refers to a case previously published, in which, after epileptiform seizures, paralysis of one leg occurred, together with exaggerated knee-jerk and ankle clonus; and says that in this case it is perfectly certain that during the paroxysm there was an excessive functional condition from the part of the mid cortex discharging to the particular muscles convulsed, and he thinks it reasonable to infer that the paralysis following the fit was due to exhaustion of corresponding fibres of the pyramidal tract, equivalent

for the time being to the destruction of the fibres; and that in cases of post-epileptiform paralysis with exaggerated knee-jerk, the exhaustion has reached the small inhibitory ganglia that Gowers has suggested may be close on the anterior horns, and the motor cells are then let go; whilst in cases where the jerk is abolished, the exhaustion has extended beyond these hypothetical inhibitory centres to the motor cells which are in turn exhausted. The multiplication of centres, especially of centres whose sole influence seems to be to control other underlying centres, does not seem to be in harmony with the reactionary tendency that now seems in process of development against the assignment of special functions to isolated groups of cells where in fact no isolation exists. Moreover, the whole inhibitory view is open to the radical objection that, so far as we see any effect from stimulation of the cortical cells, it is shown by muscular contraction instead of arrest of motion such as results from stimulation of the vagus fibres. Nor does Dr. Jackson's theory satisfactorily account for the slow development of exaggerated knee-jerk when section of the cord by disease or experiment ought to cause immediate let go; and he himself frankly admits that he by no means thinks that the hypothesis, so far as it is stated provisionally, accounts for all the facts. Indeed, it does not appear to the writer that even if Dr. Jackson's cerebral inhibitory or cerebellar controlling influence was admitted it could be considered materially to affect the fundamental principle that exaggerated jerk is due to hyper-excitability of the motor cells of the anterior cornua, since this seems to be essentially the same whether induced by exciting impulses or by "let go" from withdrawal of restraining impulses. It must, however, on the other hand be frankly admitted that no theory as yet proposed satisfactorily explains all the observed phenomena.